INSTRUCTION
2027
MANUAL

The
Microwave Mega-Node

KAY ELECTRIC COMPANY
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INSTRUCTION MANUAL

THE MICROWAVE MEGA-NODE

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SECTION I

INTRODUCTION

1.1 Description

The MICROWAVE MEGA-NODES (photograph, Fig. 1) are random noise generators designed to produce a known output noise over a frequency range of 2.60 to 12.40 kmc. They comprise a group of five separate noise sources, each utilizing a standard commercial fluorescent lamp in a JAN size waveguide.

The MICROWAVE MEGA-NODES are constructed as six separate units; five similar waveguide assemblies on hardwood stands, and a cabinet unit housing the power supply for the noise sources. Plug-in cables are provided for direct connection of the power supply to any one of the microwave units.

1.2 General Characteristics

1. Size of Waveguide and Recommended Frequency Range.

JAN No.	Outside Cross Section Dimensions	Recommended Operating Range for $TE_{0,1}$ Mode
	Inches	kmc
RG48/U	3 x 1 1/2	2.60 - 3.95
RG49/U	2 x 1	3.95 - 5.85
RG50/U	1 1/2 x 3/4	5.85 - 8.20
RG51/U	1 1/4 x 5/8	7.05 - 10.00
RG52/U	1 x 1/2	8.20 - 12.40

2. Output Impedance

Each generator presents an output impedance which is essentially matched to the impedance of the waveguide when the lamp is operated at the proper current. The VSWR of each generator is less than 1.1 over the operating range with the exception of the RG50/U guide whose VSWR goes to 1.19: 1 over about 20 percent of its range. See Figures 3-7.

3. Noise Output

The noise output of each generator is 15.84 db above thermal noise at a waveguide temperature of 32°C.

4. Dimensions and Weights

Unit	Overall Dimensions Inches	Weight lbs.
Power supply	8 x 8 x 8	7
RG48/U	24 x 8 x 5	11 1/2
RG49/U	18 x 7 x 4	5

Unit	Overall Dimensions Inches	Weight lbs.
RG50/U	17 x 6 x 3	3 1/2
RG51/U	16 x 6 x 3	2 1/2
RG52/U	16 x 5 x 3	2

5. Power Requirements

117 volts, 50 to 60 cycles, approximately 40 watts.

1.3 Purpose

The MICROWAVE MEGA-NODES provide a primary standard of noise for the indicated regions of the microwave spectrum. They may be used for the measurement of noise figure (by comparing the noise output of a system with the amount of noise introduced by the MICROWAVE MEGA-NODE), for measurement of receiver gain, and for calibration of standard signal sources. The MICROWAVE MEGA-NODES are particularly useful in checking the overall performance of radar systems.

1.4 General Circuit Considerations

1. The Fluorescent Lamp as a Noise Source.

As indicated above, the noise sources used in the MICROWAVE MEGA-NODES are standard commercial fluorescent lamps. A theory of operation for this technique has been given in an article by W.W. Mumford.* The basic hypothesis is as follows:

"In a gaseous discharge which is radiating light energy substantially monochromatically at a particular wavelength, λ_m the noise output at microwave frequencies is the same as that available from a black body which radiates its maximum energy at that wavelength."

The wavelength of maximum radiation for a black body may be determined from Wien's displacement law:

$$\lambda_m T = .289 \text{ deg. cm.}$$

where T = temperature in ^{o}Kelvin

λ_m = wavelength

It has been shown that radiation from the mercury vapor discharge in a standard fluorescent lamp is concentrated in a single spectral line ($\lambda_m = 2536.52\ (10)^{-8}$ cm). No more than about 2% of the total energy is radiated at any other wavelength. The use of the Wien law yields for this wavelength an equivalent temperature of 11,400^{o}K which, if the above hypothesis is true, represents a noise power of 15.84 db above KTB. Measurements by Mumford check this result closely.

* Bell System Technical Journal, Volume 28, number 4, October 1949, pp. 608-619.

Mumford has found that the noise output of a fluorescent lamp is substantially independent of fluorescent coating and of current density, but is slightly affected by temperature. Since Mumford's measurements of absolute noise output power were made with a guide temperature of 32°C, a temperature correction should be made of the calculated noise output for guide temperatures of different value. Both Mumford and Johnson of R.C.A. have arrived at a closely similar temperature correction factor, 0.05 db per degree centigrade. Each noise generator unit of the MICROWAVE MEGA-NODES is equipped with a permanently installed thermometer for rapid determination of the temperature correction.

2. Waveguide Terminations

All of the waveguides of the MICROWAVE MEGA-NODES are terminated at one end in a standard JAN cover flange. In the RG48/U and 49/U guides, the opposite end is similarly terminated in a flange; in the RG50/U, 51/U and 52/U guides, the opposite end is terminated in short circuit.

It has been determined that the RG48/U and 49/U guides may be inserted in a section of line without introducing serious discontinuities provided that the lamp is in position and is turned off. That is, these units may be connected between a receiver and a matched load and present a matched load to the receiver both at room temperature with the lamp turned off and at 11,400°C with the lamp on. For this reason, flanges have been provided at both ends of these guides.

In the other three guides, the discontinuities introduced by the de-energized lamp are more serious and prohibit the use of this technique. These guides have been terminated in short circuit to prevent radiation from the unused end.

3. Effect of Opposite End Terminations on Noise Output

The available power output of the noise source is substantially independent of the termination at the opposite end of the waveguide. This condition is brought about by the insertion losses introduced in the guide by the ignited lamp. The magnitude of these losses is such that substantially none of the power radiated away from the receiver and reflected from the opposite termination (whether short or open) will appear at the receiver end of the guide. The termination of the unused end is therefore unimportant with the lamp ignited, except for the possible leakage problem encountered with poorly shielded receivers. It would be possible to obtain 15.84 db of noise from each end of the generator at the same time if desired.

4. VSWR

A low VSWR (and the insertion loss mentioned above) are obtained by tilting the tube at an acute angle to the guide. Although the lamp at any one point is not matched to the guide impedance, the reflections from the various points of the lamp (there are several wavelengths of the lamp in the guide) cancel each other out to a large extent. The actual impedance match

of the lamp to the guide is modified only slightly by the lamp current. Good results may be obtained over the entire recommended operating range of each of the waveguides employed by operating the lamp at the currents shown in figures 1-5.

One of the problems encountered in the use of fluorescent lamps as noise sources has been the presence of audio oscillations across the lamp. No method of eliminating the oscillations by external circuits is known; and as can be seen from the curve on VSWR, the impedance match of the lamp to the guide is affected by lamp current. If, then, the current varies at an audio rate, the impedance of the generator will vary at the same rate, and the power delivered by the generator to a constant load will be similarly modulated. However, in the MICROWAVE MEGA-NODES, where the lamp is mounted at an acute angle to the waveguide, the variation of impedance with tube current is extremely small. Since the actual tube current variations due to these oscillations are also small, the output impedance variation is almost negligible. It has not been possible to see other than random noise in the output of a receiver under test with these generators.

5. Power Supply

The MICROWAVE MEGA-NODE power supply, Figure 2, will operate any of the noise generators. It is a well-filtered, variable-current supply containing a starter for the lamp and an output current control. Lamp current is indicated on a panel-mounted milliammeter.

SECTION II

OPERATION

2.1 Operating Data

1. Fluorescent Lamp

A standard commercial lamp is used in each of the generators. A T5, 8 watt, white fluorescent lamp is furnished with the RG49/U, 50/U, 51/U and 52/U guides; and a T8, 15 watt, white fluorescent lamp is furnished with the RG48/U guide.

2. Operating Current

Each generator must be operated at a particular current in order to insure a good impedance match between generator and guide. See Figures 3-7.

3. Temperature Indication

A thermometer is mounted permanently in position on each waveguide to measure guide temperature for noise output corrections.

4. Power Cords

An A-C line cord with plug and two lamp connector cords with double-ended connectors are furnished and may be housed in a compartment at rear of power supply when not in use. The lamp connectors are of such design as to enable them to be used with either the 8-watt or 15-watt lamps.

5. Polarity Switch

The polarity switch reverses the polarity of the potential applied to the lamp. The lamp will operate satisfactorily with the switch in either position (+ or -). If left on one position for long periods of time, the cathode material will deposit on the bulb wall at one end only. This discoloration does not affect the noise output of the lamp. However, the life of the tube will be shortened if the polarity switch is left in one position. It is advisable to alternate switch positions every 10 to 15 minutes during operation, or if only used for short periods of time, the switch should be thrown to the opposite position when turning the Power Supply off. Failure to observe this precaution will not cause any inaccuracy of measurements.

2.2 Operating Instructions

1. Connect the noise generator to the input of the receiver under test by means of the standard waveguide flange. Either end of the RG48/U or RG49/U may be used. The unused end may be terminated in a matched load (see Methods of Noise Figure Measurement), left open, or shorted with one of the shorting plates provided.

Insert the lamp in the slanted tube.

WARNING - Ordinary fluorescent lamps contain some beryllium powder. Beryllium in many forms is poisonous and care should be taken in handling any fluorescent lamp to prevent breakage (see Physics Today, June 1949).

Plug the connectors onto each end of the lamp. The plugs are not polarized and there is no requirement for alignment of the pins. The power supply connector is then mated to the generator cable plug.

2. With the power supply plugged into a 117 volt, 50 to 60 cycle outlet, throw the power switch to the on position. The pilot lamp on the front panel should light.

A. Turn the Increase Current Control full counterclockwise.

B. Depress the Start-Run switch and adjust the Increase Current Control so that the Lamp Current meter reads full scale.

C. After 10 to 15 seconds, release the Start-Run switch. The lamp should light. This may be noted by direct observation of the lamp or by noting that the Lamp Current meter remains upscale. If the lamp has failed to light, the current will read zero. If so, depress the Start-Run switch again and release after another 10 to 15 seconds. Be sure to give the filament adequate time to heat (depressed position).

D. Adjust the Increase Current control so that the Lamp Current meter indicates the value recommended in Figures 3-7.

NOTE: Be sure to check the value of current required at the frequency at which the receiver under test is operated.

E. The generator is now operating and is producing random noise across the entire useful frequency range of the guide at 15.84 db above thermal noise.

F. Check the waveguide temperature with the thermometer which is attached to the wall of the generator. The actual output may be calculated from the formula

$$P_{out} = (15.84 - 0.05k) \text{ db above KTB}$$

where k = number of degrees centigrade above $32^{\circ}C$. at which the waveguide is operated. If the waveguide temperature is below $32^{\circ}C$., k is negative and the generator output is higher than 15.84 db above KTB.

G. It is recommended that a 15 minute warmup be allowed in order to allow the waveguide to reach a constant temperature. However, the generator may be used immediately after it is turned on if care is taken in taking temperature readings for each measurement at the same time that the measurement is made.

SECTION III

THEORY AND TECHNIQUES OF NOISE MEASUREMENT

The literature on the subject of noise figures and their measurement is extensive. One article by H.T. Friis which appeared in the 1944 Proceedings of the IRE, page 419, provides a good basic approach to the subject. The definition of noise figure as given by Friis is

$$F = \frac{\text{available signal to noise ratio at input of network}}{\text{available signal to noise ratio at output of network}}$$

This basic equation can be modified in a number of ways depending on the method used for making the particular measurement. For example, if a signal generator is used as a power source, the equation may be modified to

$$F = S_g/mKTB \qquad (1)$$

where S_g is the available power from the source

m is the ratio of signal power to noise power at the output

K is Boltzman's constant

T is the absolute temperature in degrees Kelvin

B is the bandwidth over which the noise is observed.

If on the other hand, a hot-body noise source is used, the equation for noise figure may be written as

$$F = \left[(T_2/290)-1\right] /(Y-1) \qquad (2)$$

where T_2 is the effective temperature of the hot body and

Y is the ratio of the noise power available from the network when the source is at T_2 to that when it is at room temperature.

A number of methods of making measurements premised on these two equations are available. Let us first concentrate our attention on the case of a microwave receiver for which the MICROWAVE MEGA-NODES were specifically designed. These methods generally fall into two separate categories:

1) those in which the output of the noise generator is coupled directly to the receiver and Y in equation (2) is measured and

2) those in which the amount of power coupled from the noise generator to the receiver under test is varied until the output noise power, S_g in equation (1), in the absence of the generator has been doubled.

It should be noted that the noise power from the MICROWAVE MEGA-NODES is fixed and cannot be varied by changing element voltages or currents. Several techniques of making noise figure measurements using the MICROWAVE MEGA-NODES are listed below.

I. DIRECT COMPARISON: The receiver under test is connected to the MICROWAVE MEGA-NODE as in Figure 8. If the RG48/U or RG49/U MEGA-NODES are employed, the solid line diagram may be used, since both ends of the guide are equipped with flanges. The Z_o load is connected to one end and the receiver to the other. With the fluorescent lamp off, the receiver gain is adjusted to give a convenient reading P_1 on the power indicator. The lamp is then turned on and the new output power reading P_2 is noted. Y is determined as the ratio of the power out with the lamp on to that with the lamp off ($Y = P_2/P_1$) and the noise figure is determined from equation (2). T_2 for the lamps used is 11,394°K which gives $(T_2/290)-1$ equal to 38.29. Therefore

$$F = \frac{38.29}{Y-1} \quad \text{(F in power ratio)} \qquad (3)$$

where Y is the ratio of the output noise power with the MICROWAVE MEGA-NODE on to that with the Mega-Node off.

If the RG50/U, RG51/U, or RG52/U guides are employed, the Z_o load and the Mega-Node should be alternately connected to the input to the receiver to determine Y. In these units, the discontinuity introduced by the cold lamp is such that it cannot be used as a transmission device and the unused end is therefore terminated in a short circuit. The RG48/U and RG49/U guides may be used in the same manner by using the end plate supplied to produce a short circuit at the unused end of the generator.

It should be emphasized that great care should be taken to ascertain that no overload is occuring in the receiver and to determine the law of the power indicator. This may be checked by measuring an input-output characteristic of the receiver and power indicator with a calibrated signal generator. Since noise contains components whose amplitude for short periods may be much greater than the rms noise power, it is important that no overload occur at c-w levels about four times the noise levels encountered.

II. INSERTED ATTENUATION: One way to eliminate the necessity for calibration of the output characteristic of the receiver is to use either a precision i-f or an r-f attenuator, or both. If the noise figure of the receiver under test is very low, the full output power of the MICROWAVE MEGA-NODE will give a Y factor that is large and the receiver must have high output power capabilities if overload is to be avoided. Most receivers, however, can handle an output power of twice that due to noise alone. If, then, an r-f attenuator is placed between the Mega-Node and the input of the receiver (see Figure 9), the attenuation may be adjusted to give an output power twice that available with the receiver input terminated in the normal input impedance. This means that Y = 2.

F may then be calculated from the formula,

$$F = (15.84 - \alpha) \text{ db} \qquad (4)$$

where α is the inserted attenuation.

If it is possible to insert a precise amount of attenuation in the i-f amplifier (such as when the amplifier is composed of a pre-amplifier and main amplifier), this system becomes even simpler. The noise output of the receiver with Z_o input termination is adjusted to a convenient value. Then with the MICROWAVE MEGA-NODE connected to the input through the r-f attenuator, a 3 db i-f attenuator is inserted (see Figure 10). The r-f attenuator is adjusted to return the power indicator to the same reading as before. The noise figure may then be calculated by equation (4). Since, then, the power indicator is always operating at the same level, and on the same kind of signal (noise) under both conditions of the measurement, overload effects are less important and very simple power indicators may be used. This is true, of course, only if the 3 db i-f attenuation is introduced at a low level in the amplifier before overload occurs. A simple measurement of second detector rectified d-c is a satisfactory indication of relative power output under these circumstances.

One other advantage of the above scheme is that normal r-f attenuators may be adjusted to give high insertion loss, so that with the lamp off and the attenuator full in (20 db or more), the receiver effectively will "see" an input termination sufficiently close to Z_o that it is not necessary to disconnect the MICROWAVE MEGA-NODE and connect a Z_o load.

If only the i-f attenuator is available, the above method with slight variation may be employed, retaining the "constant output" technique. Sufficient i-f attenuation is inserted to bring the power output reading back to the original reading (with Z_o at room temperature at the input). The noise figure may then be calculated from the following

$$F = 15.84 - 10 \log_{10} (A-1) \text{ db}$$

where A is the i-f attenuation expressed as a power ratio.
For example, if the required i-f attenuation was 6 db; that is, a power ratio of 4

$$F = 15.84 - 10 \log_{10} (4-1)$$

$$= 15.84 - 4.77 = 11.07 \text{ db},$$

or if only 1.5 db (1.41) were required

$$F = 15.84 - 10 \log_{10} (1.41-1)$$

$$= 15.84 + 3.87 = 19.71 \text{ db}$$

In the preceding discussion, it has been assumed that the guide temperature was 32°C. If not, the correction factor of -0.05 $^{db}/_{°C}$ above 32°C must be added to all measurements. Furthermore, no mention has been made of matching sections between the MICROWAVE MEGA-NODE and the receiver under test. None should be used. The Mega-Nodes have been designed to present a matched load to the line connecting them to the receiver terminals. If a matching device is needed to increase the efficiency of power transfer between Mega-Node and receiver, it indicates a mismatch at the receiver terminals. Friis' definition of noise figure specifically rules out matching devices--he uses the available power from the source and not the power transferred from source to receiver. Any loss of power in the transfer should be reflected in a poorer noise figure for the receiver, if the receiver is to operate from a Z_o source in the field.

Also, it has been tacitly assumed that the receiver had only a single response--no spurious responses, such as images or harmonics. If spurious responses are present, the noise from the Mega-Node will be accepted by the receiver on these responses (if they are in the frequency range of the Mega-Node) as well as in the desired channel. The accepted definition of noise figure employs the concept of the "useful channel bandwidth",* and if a noise generator is used in the noise figure measurement, a correction must be made to account for spurious receiver responses. If F is the noise figure as measured by the above methods and F_t is the true noise figure, both expressed as power ratios,

$$F_t = F \frac{B}{B_u}$$

where B is the total bandwidth including spurious responses, and

B_u is the useful channel bandwidth

For example, when measuring a receiver which has a complete image (image response equal to the desired response), the ratio B/B_u is 2, and 3 db must be added to the measured noise figure to obtain the true noise figure.

* See discussion of Friis by D.C. North, Proceedings of the IRE, 1945 pages 125-127.

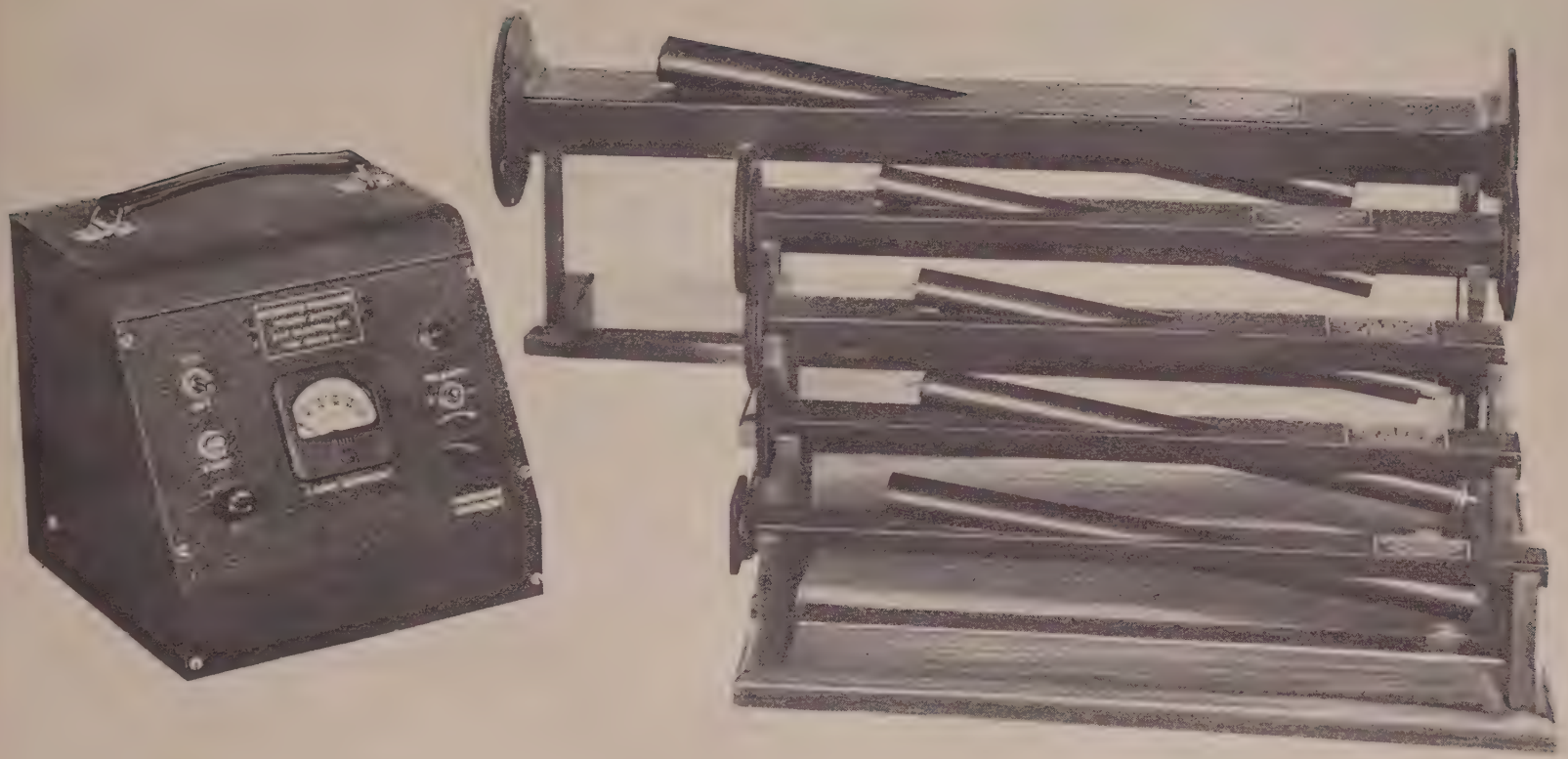
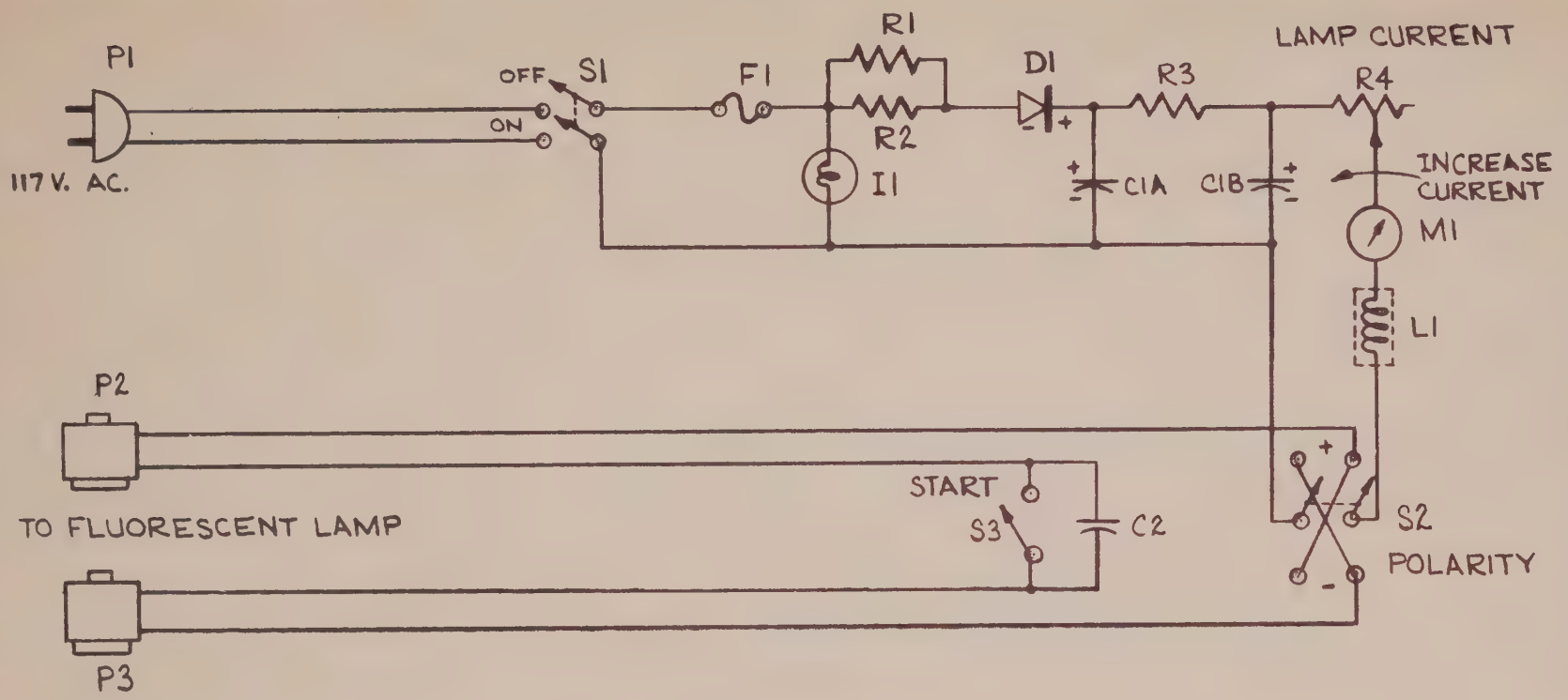


FIG. 1



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MICROWAVE MEGA-NODE
POWER SUPPLY
SCHEMATIC DIAGRAM FIG. 2
KAY ELECTRIC CO. PINE BROOK, N.J.

PARTS LIST

MICROWAVE MEGA-NODE

Tubes

8 or 15 watt fluorescent lamp

Resistors

R1	10 ohms	2 watt	
R2	10 "	2 "	
R3	200 "	20 "	
R4	1000 "	25 "	Pot. INCREASE CURRENT

Condensers

C1 A,B	40-40 mfd.	150 V.	Electrolytic
C2	.005 mfd.	600 V.	Paper

Coils

L1	Ballast	GE 58G690

Crystals

D1	Selenium rectifier 250 ma. F.T.R. 404D3450A

Connectors

P1	AC line plug
P2, P3	Fluorescent lamp connectors

Switches

S1	D.P.S.T.	ON-OFF
S2	D.P.D.T.	POLARITY
S3	S.P.S.T. Momentary	START

Meter

M1	0-300 ma milliammeter

Fuse

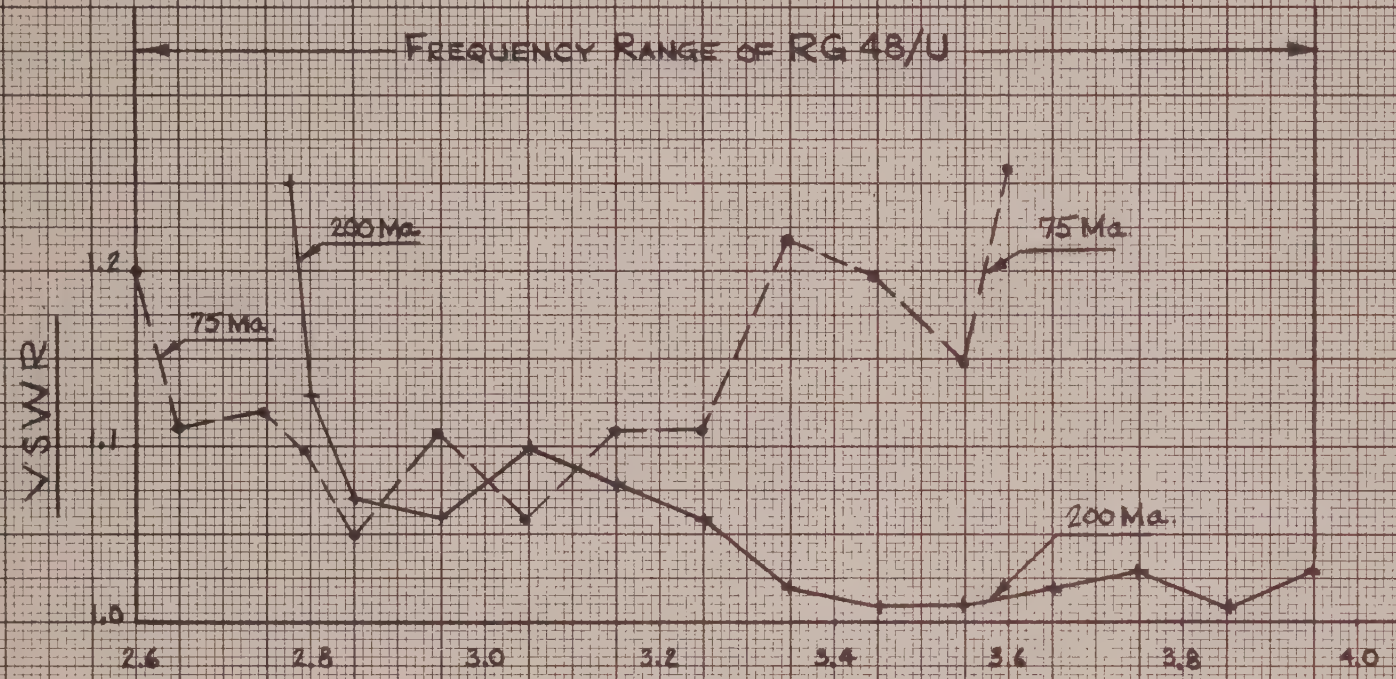
F1	1 Amp.

Pilot Lamp

I1	120 V. 6 Watt	Screw Type

VSWR vs. Frequency For RG 48/U

RG 48/U (1 1/2 x 3)
15 Watt T8 Lamp
Unused End of Waveguide Shorted



Frequency in KMc.

Fig. 3

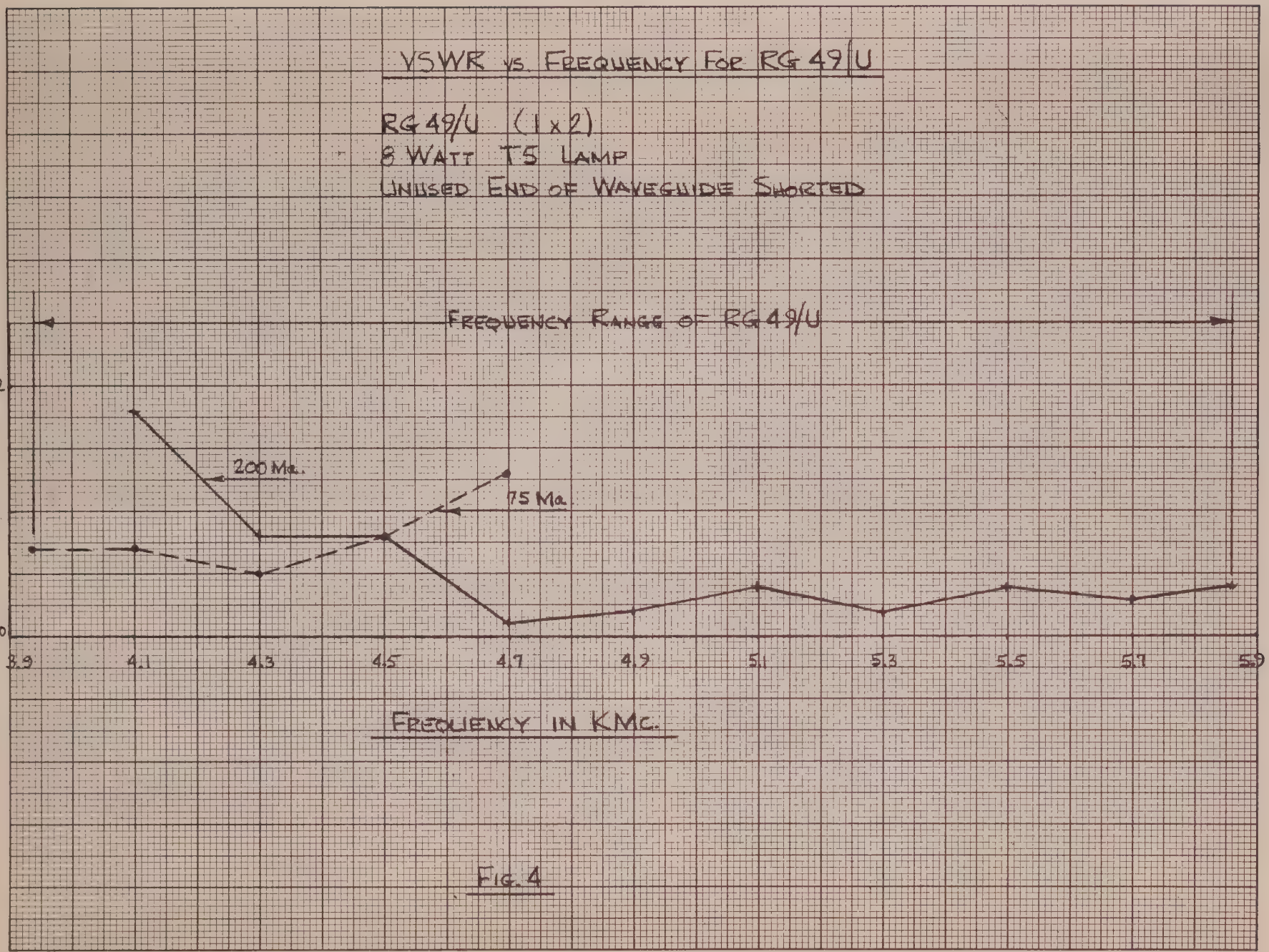
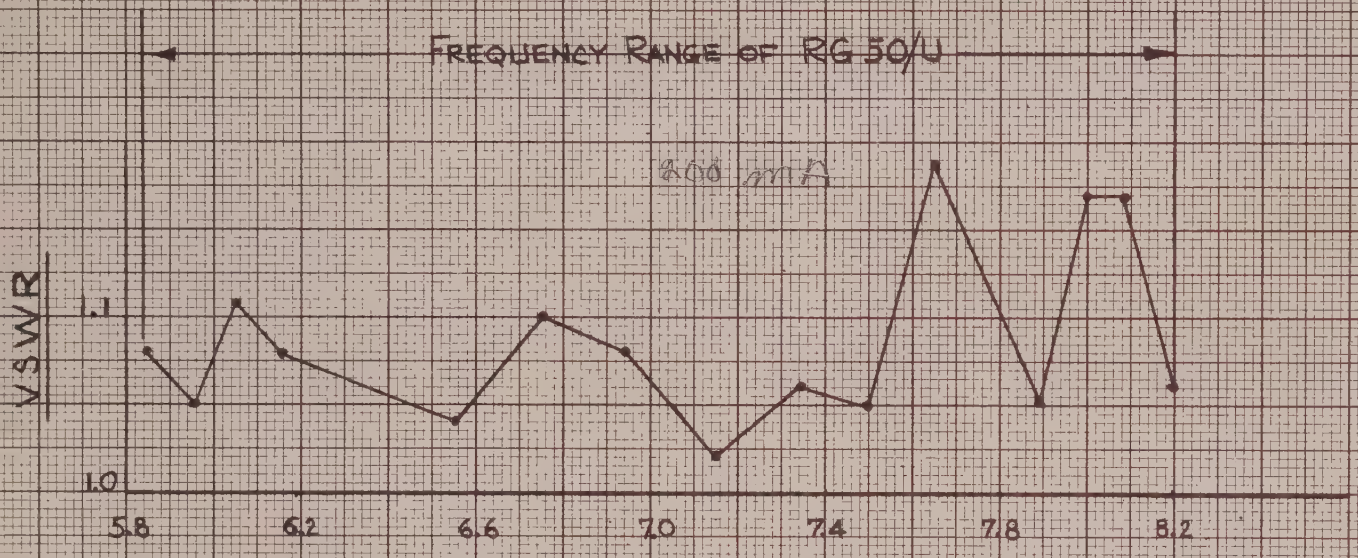

VSWR vs. Frequency For RG 49/U
RG 49/U (1 x 2)
8 Watt T5 Lamp
Unused End of Waveguide Shorted
Frequency Range of RG 49/U
VSWR
1.2
1.1
1.0
200 Ma.
75 Ma.
3.9
4.1
4.3
4.5
4.7
4.9
5.1
5.3
5.5
5.7
5.9
Frequency in KMc.

Fig. 4

VSWR vs. Frequency For RG 50/U

RG 50/U (3/4 x 1 1/2) Waveguide
8 Watt T5 Lamp



Frequency in KMc.

Fig. 5

VSWR vs. Frequency For RG 51/U

RG 51/U (5/8 x 1 1/4)
8 Watt T5 Lamp

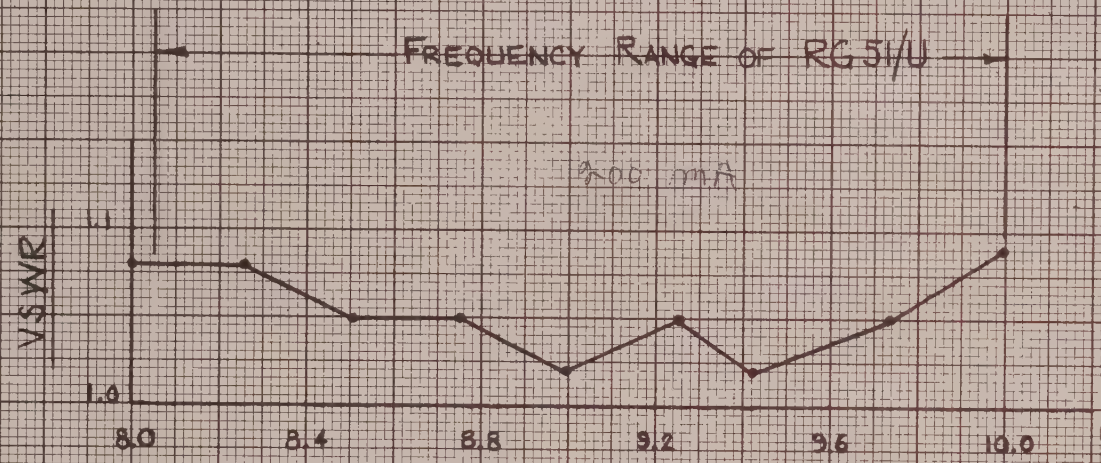


Fig. 6

VSWR vs. Frequency For RG 52/U

RG 52/U (1/2 x 1)
8 Watt T5 Lamp

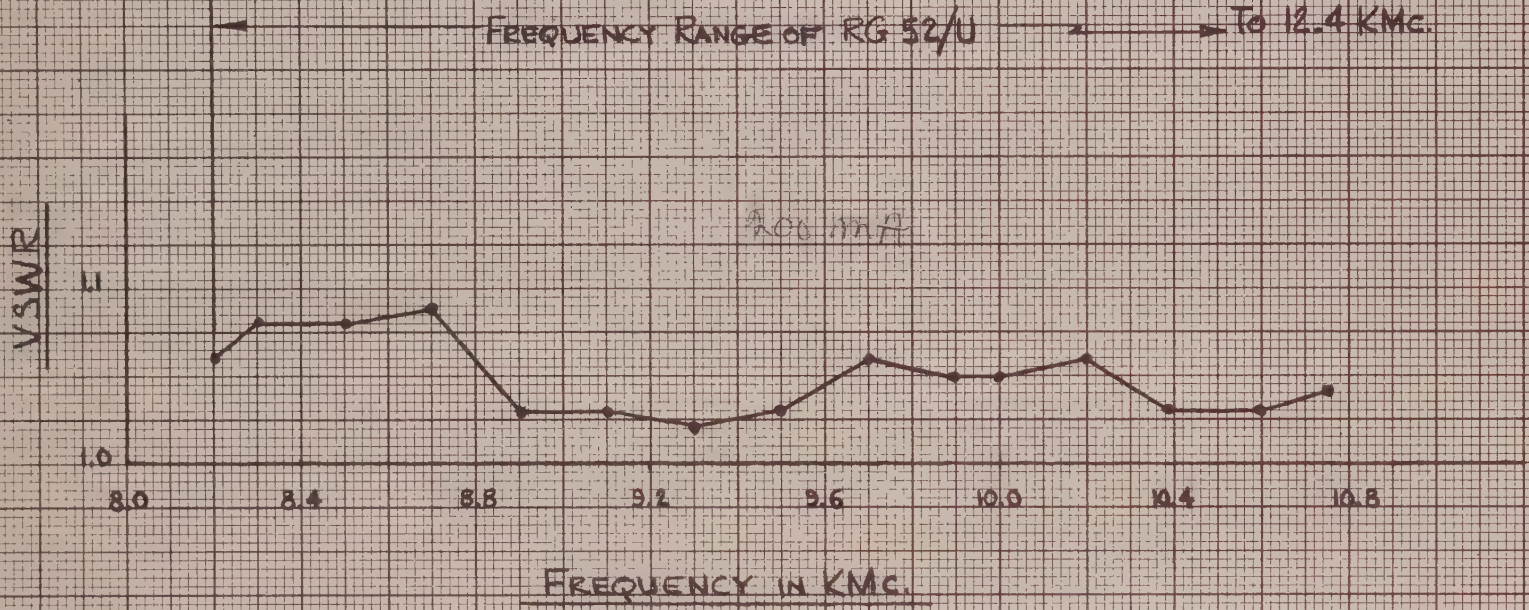


Fig. 7

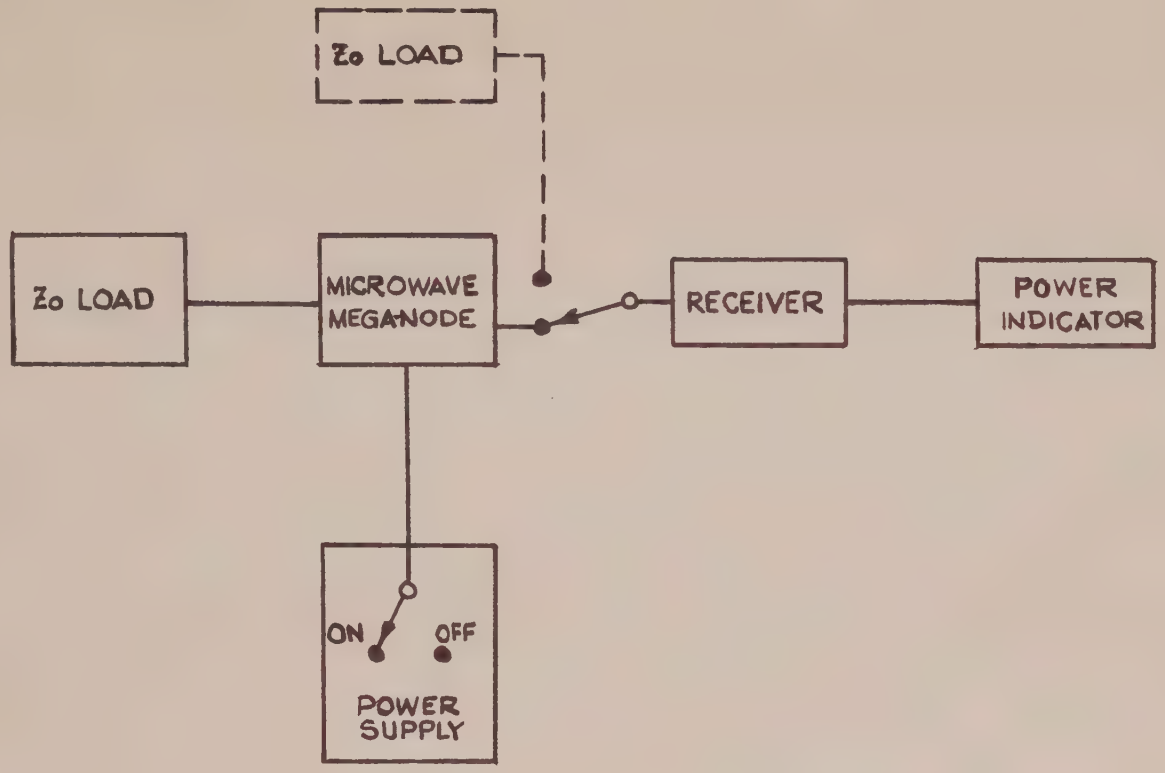


FIG. 8

NOISE FIGURE MEASUREMENTS BY DIRECT COMPARISON

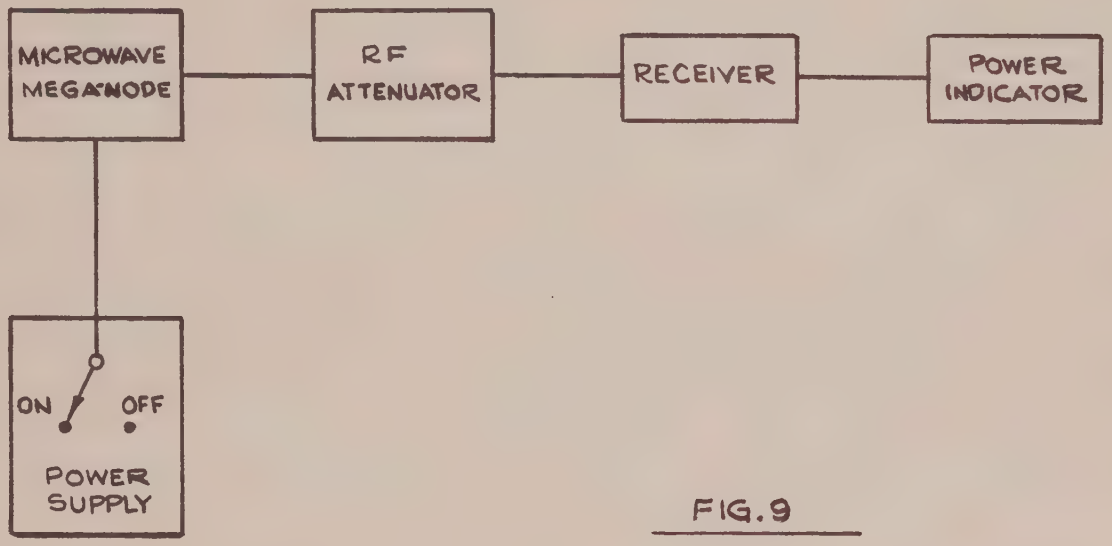


FIG. 9

NOISE FIGURE MEASUREMENTS WITH INSERTED ATTENUATION

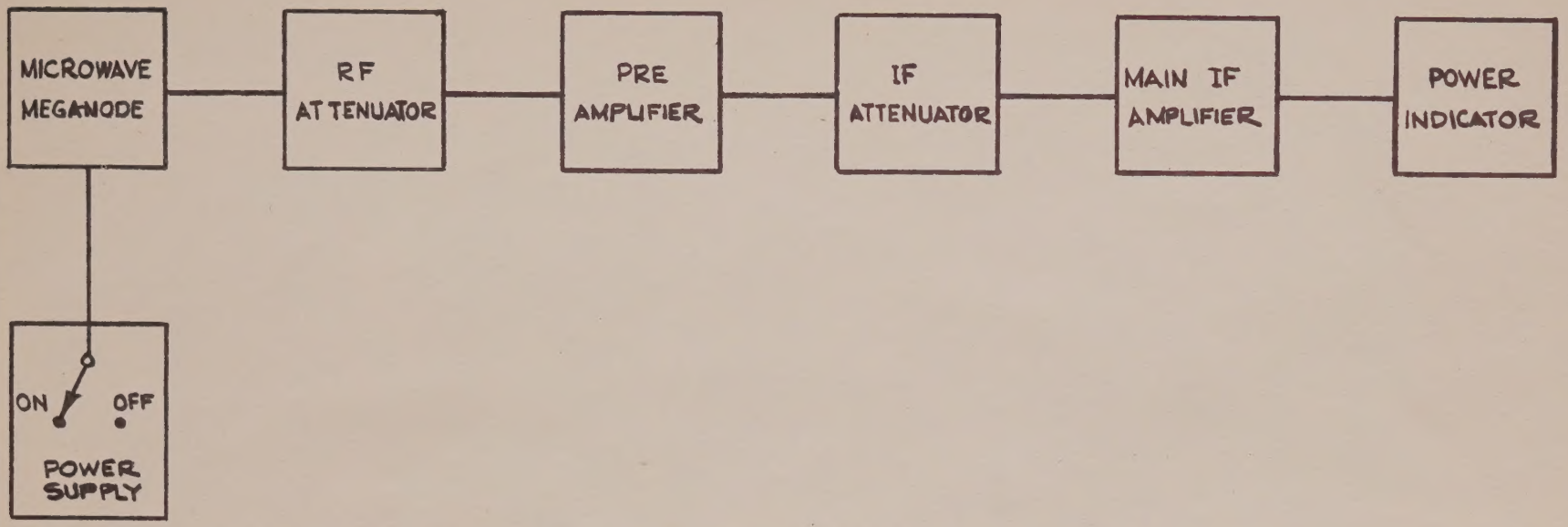
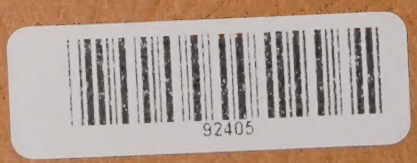


FIG. 10

NOISE FIGURE MEASUREMENTS WITH DOUBLE INSERTED ATTENUATION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